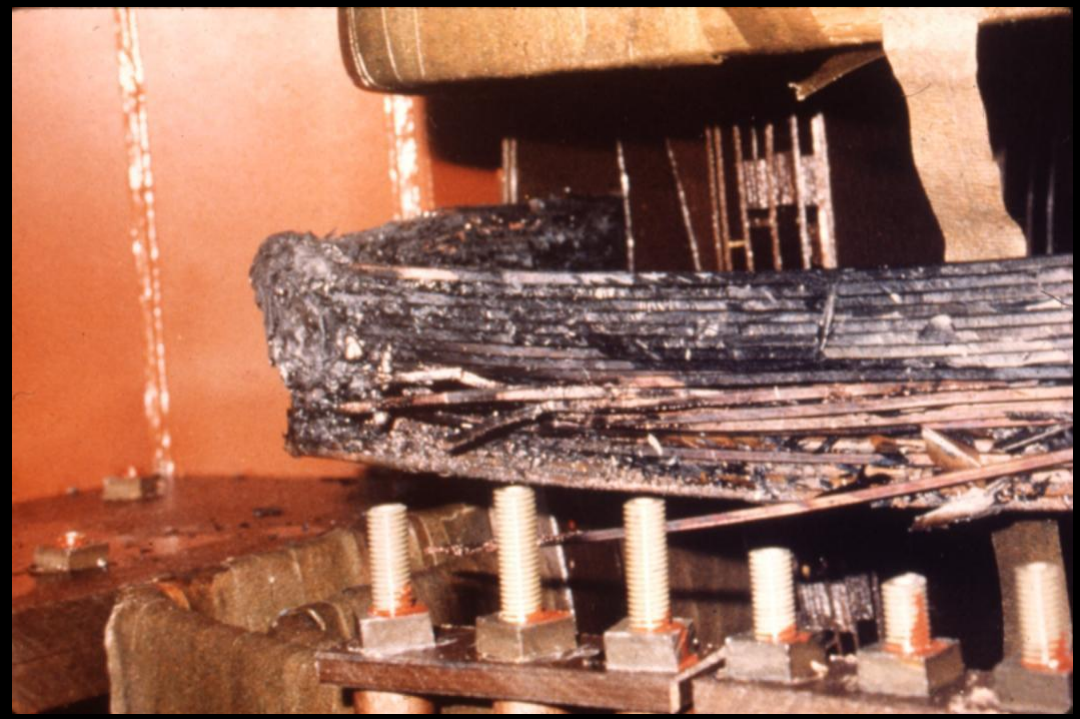
In 1989, A Massive Blackout Left Millions without Power for Twelve Hours

Image from a NASA Artist's Concept

Transformer Damaged from Geomagnetically Induced Current (GIC)



Images Provided by J.G. Kappenman, used with permission.

Short-wave Radio Communications Affected

Jammed radio signals into Russia from Radio Free Europe

Audio is provided with permission from amateur radio astronomer, Radio Jove participant,
and
NASA Citizen Scientist Thomas Ashcraft.

Auroral Oval Moved South (North) Toward the Equator, Aurorae Seen in Florida

Jan 20, 2016: Image taken from the International Space Station (ISS) by
NASA astronaut Scott Kelly and European Space Agency (ESA) astronaut Tim Peake.
Lights from the Pacific Northwest are seen below the Aurorae.

What Caused these Problems?
i.e., Power Outage, Short-Wave Fade,
Aurorae Seen far to South (or North)
Could it be:

Earthquakes?

Tornadoes?

Hurricanes?

Alien Invasion?

Now Let’s Pause for a Poll!

https://pollev.com/mitziadams505

Are you:

A. Male

B. Female

C. Do not wish to say

What is your age (if you wish to say)?

A. Less than 10

B. Between 10 and 20

C. Between 20 and 30

D. Between 30 and 40

E. Between 40 and 50

F. Greater than 50

Rate how interested you are in space science.

A. Not at all interested

B. Moderately interested

C. Interested

D. Super interested

The Sun is a star.

A.
True

B.
False

Is a sunspot cooler than its surroundings?

A. Yes

B. No

C. Maybe

Aurorae are caused by solar-wind particles hitting Earth's atmosphere.

A. True

B. False

What Caused these Problems?
i.e., Power Outage, Short-Wave Fade,
Aurorae Seen far to South (or North)
Could it be:

Earthquakes?

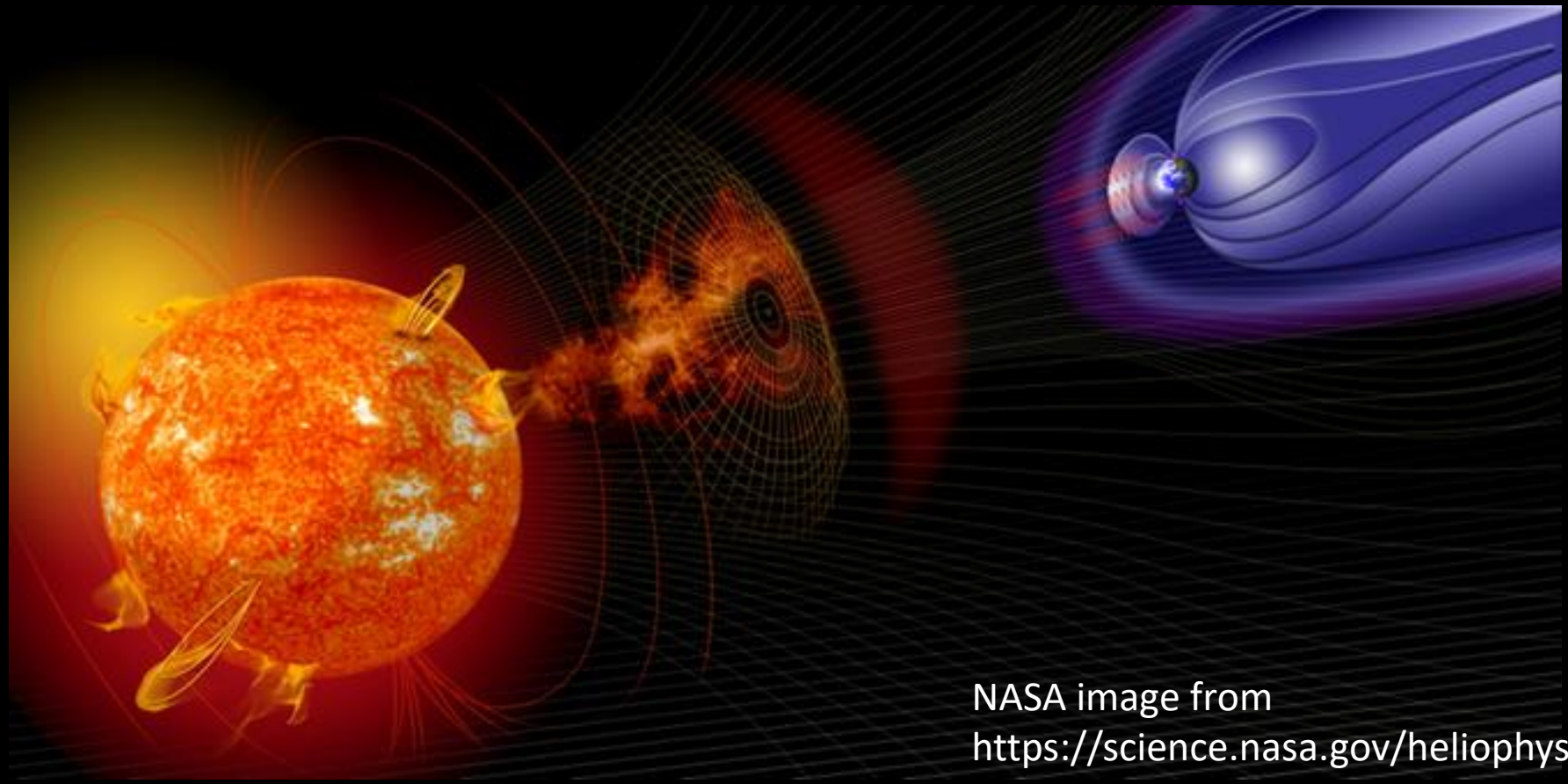
Tornadoes?

Hurricanes?

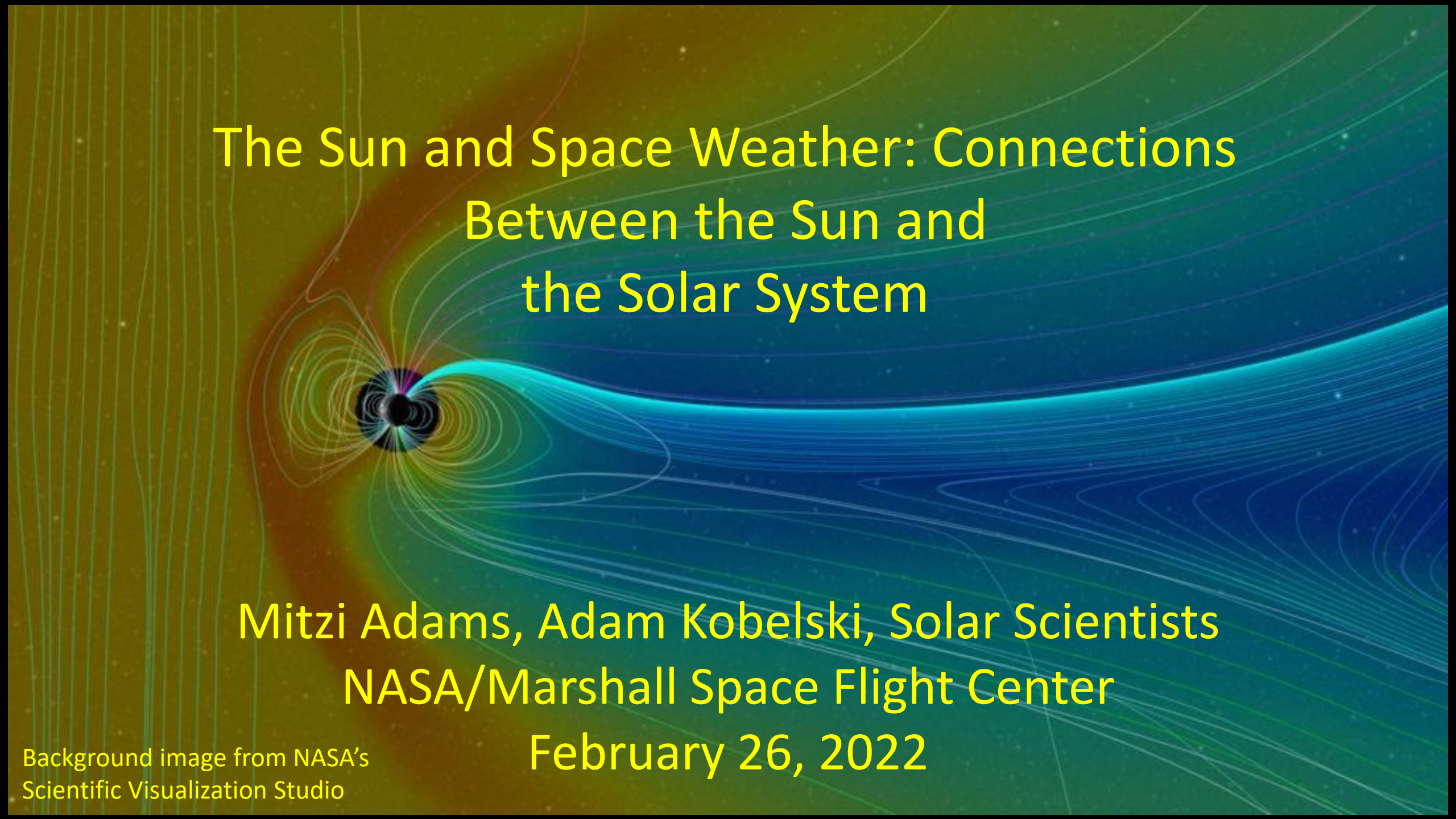
Alien Invasion?

The Answer Is ---

Space Weather!



NASA image from
https://science.nasa.gov/heliophysics/space-weather



The Sun and Space Weather: Connections Between the Sun and the Solar System

Mitzi Adams, Adam Kobelski, Solar Scientists
NASA/Marshall Space Flight Center

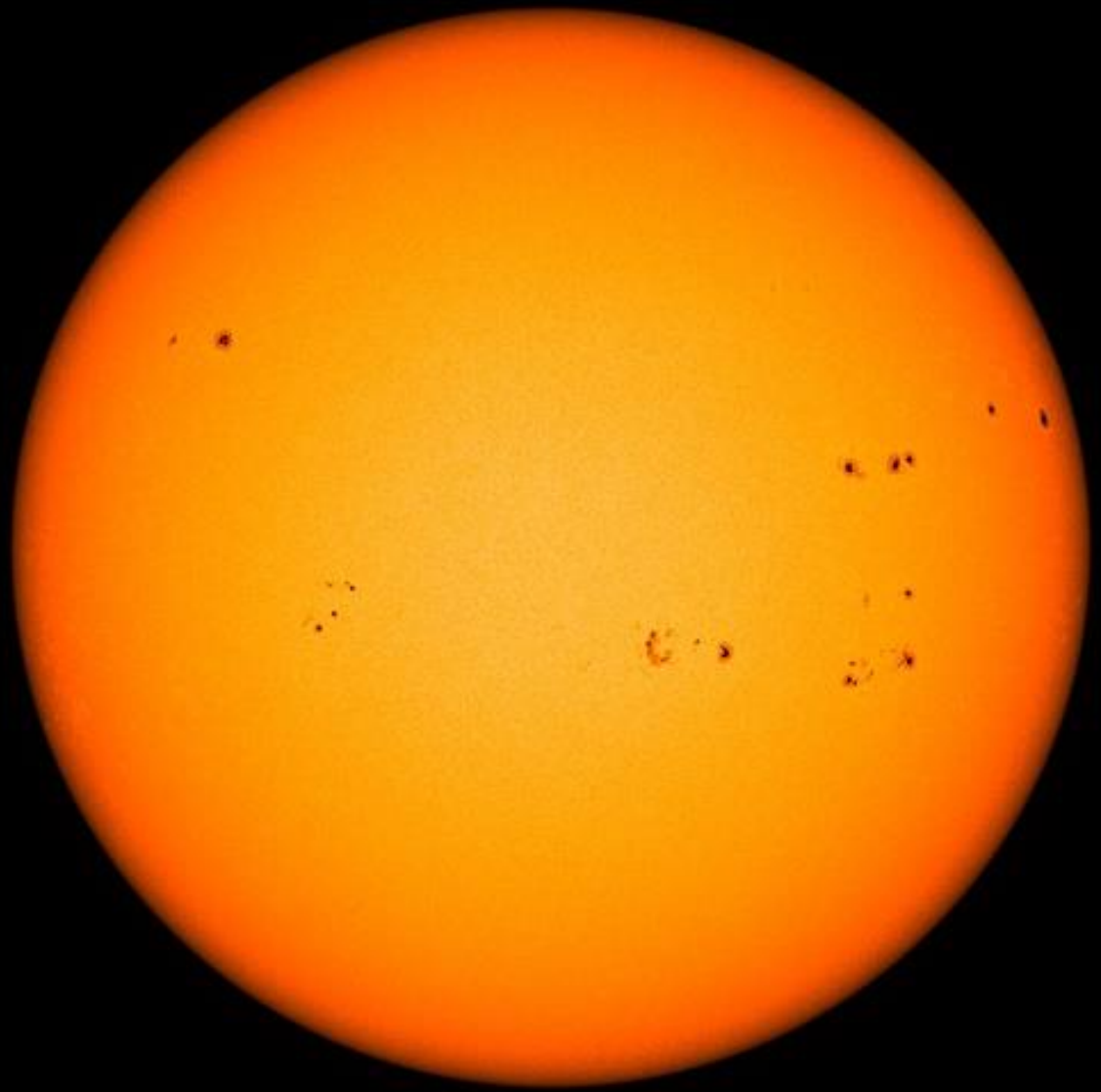
February 26, 2022

Background image from NASA's Scientific Visualization Studio

Space Weather: Starts with the Sun, our Closest Star

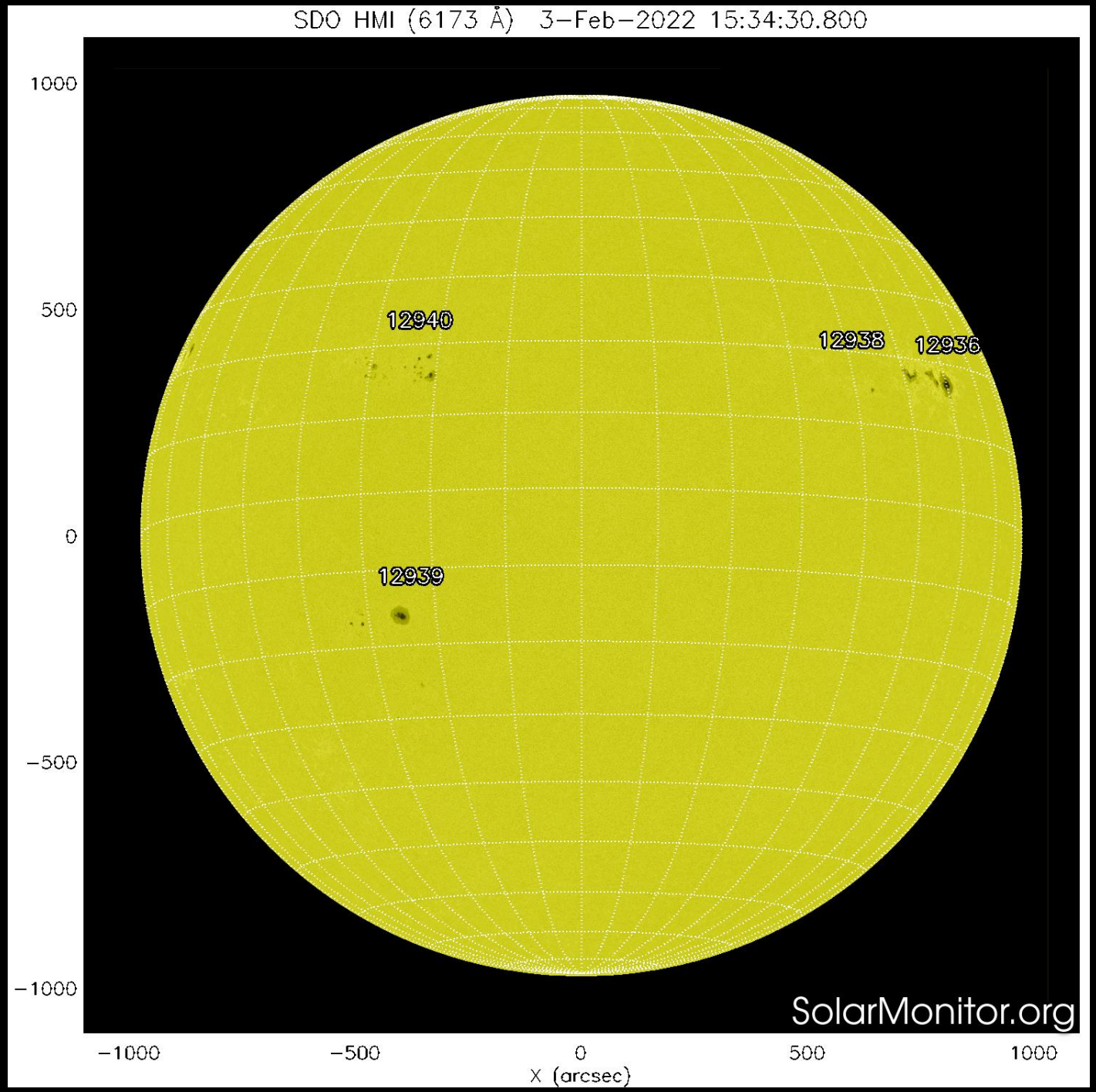
The Sun is a Star

The Sun produces light all “colors” of the EM spectrum:
γ rays, X rays, UV, visible, IR, μwave, radio.



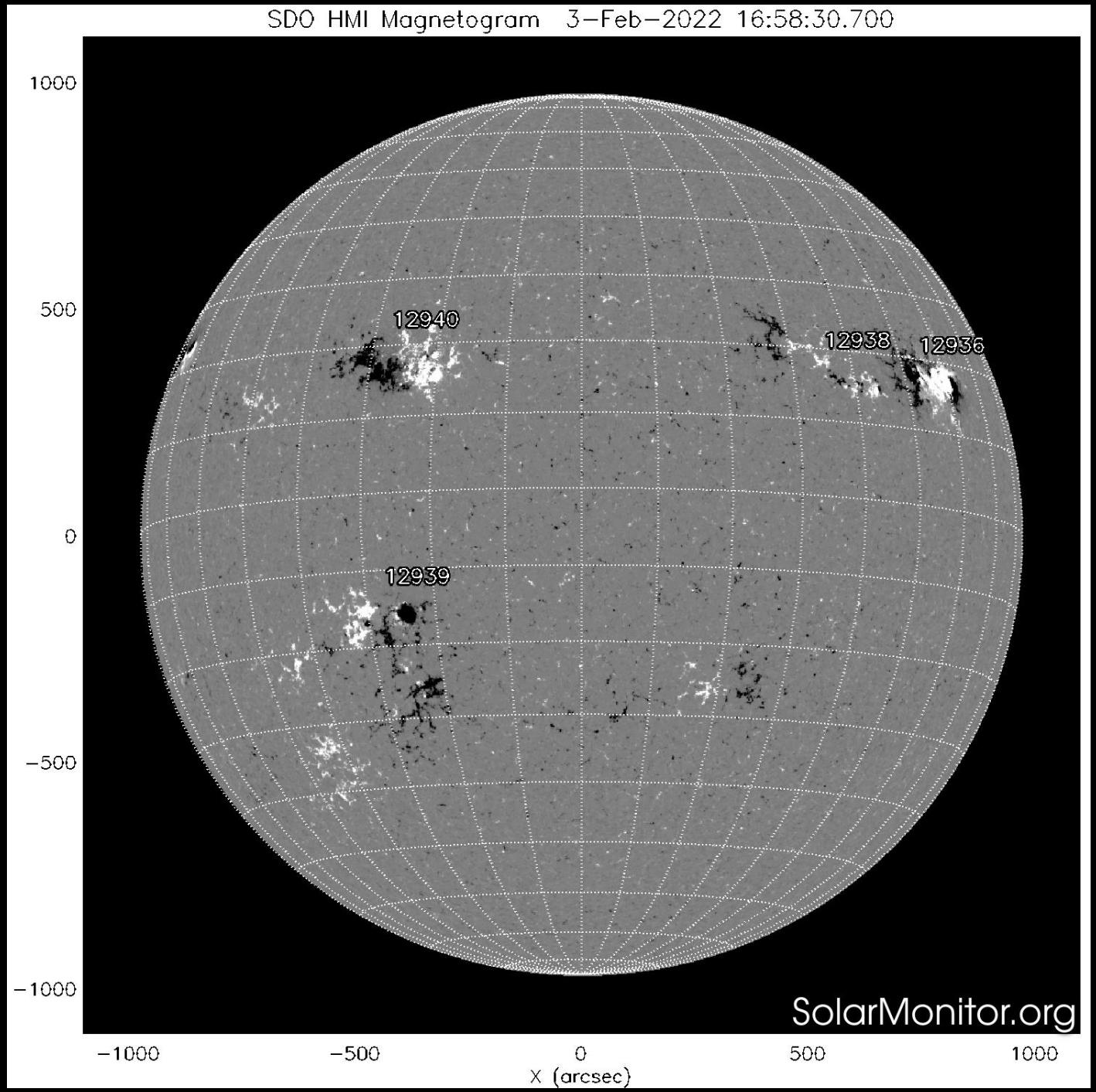
The Sun produces a “wind” of charged particles, electrons and protons, which flows steadily all the time.

The Photosphere — with Sunspots!



This Recent Image from the Solar Dynamics Observatory Shows Sunspots

The Unspotted Area is About 6000 K (10,000 F) Sunspots are About 3700 K (6200 F) in the Darkest Part of the Sunspot (Umbra)



This Image, also from the Solar Dynamics Observatory Shows the Magnetic Field that Gives Rise to the Sunspots

Sunspots are Cooler than their Surroundings Because the Magnetic Field Holds Back Heat from Below

Now We Pause for a Poll!

https://pollev.com/mitziadams505

The Sun is a star.

A.
True

B.
False

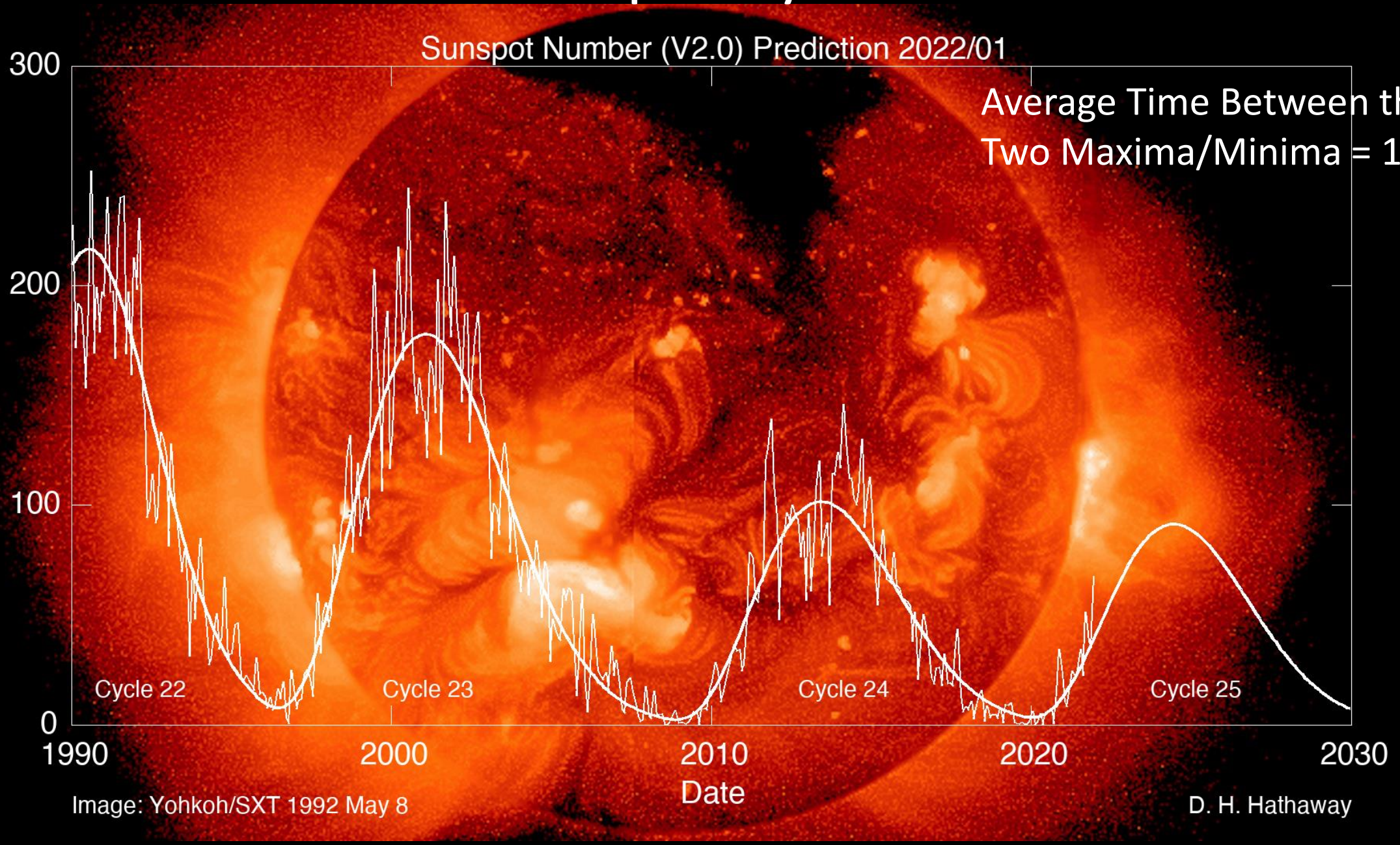
Is a sunspot cooler than its surroundings?

A. Yes

B. No

C. Maybe

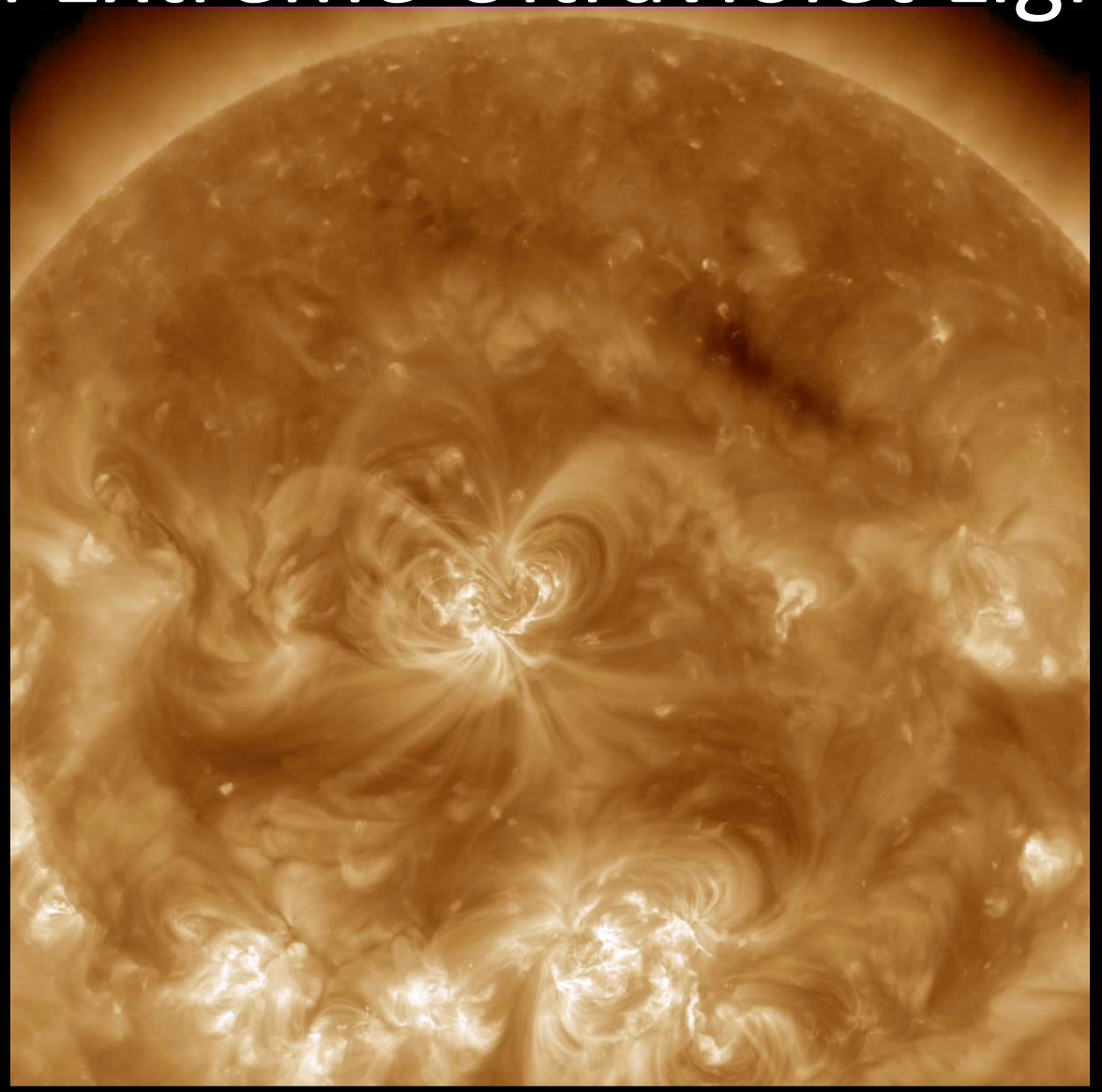
Sunspot Cycle

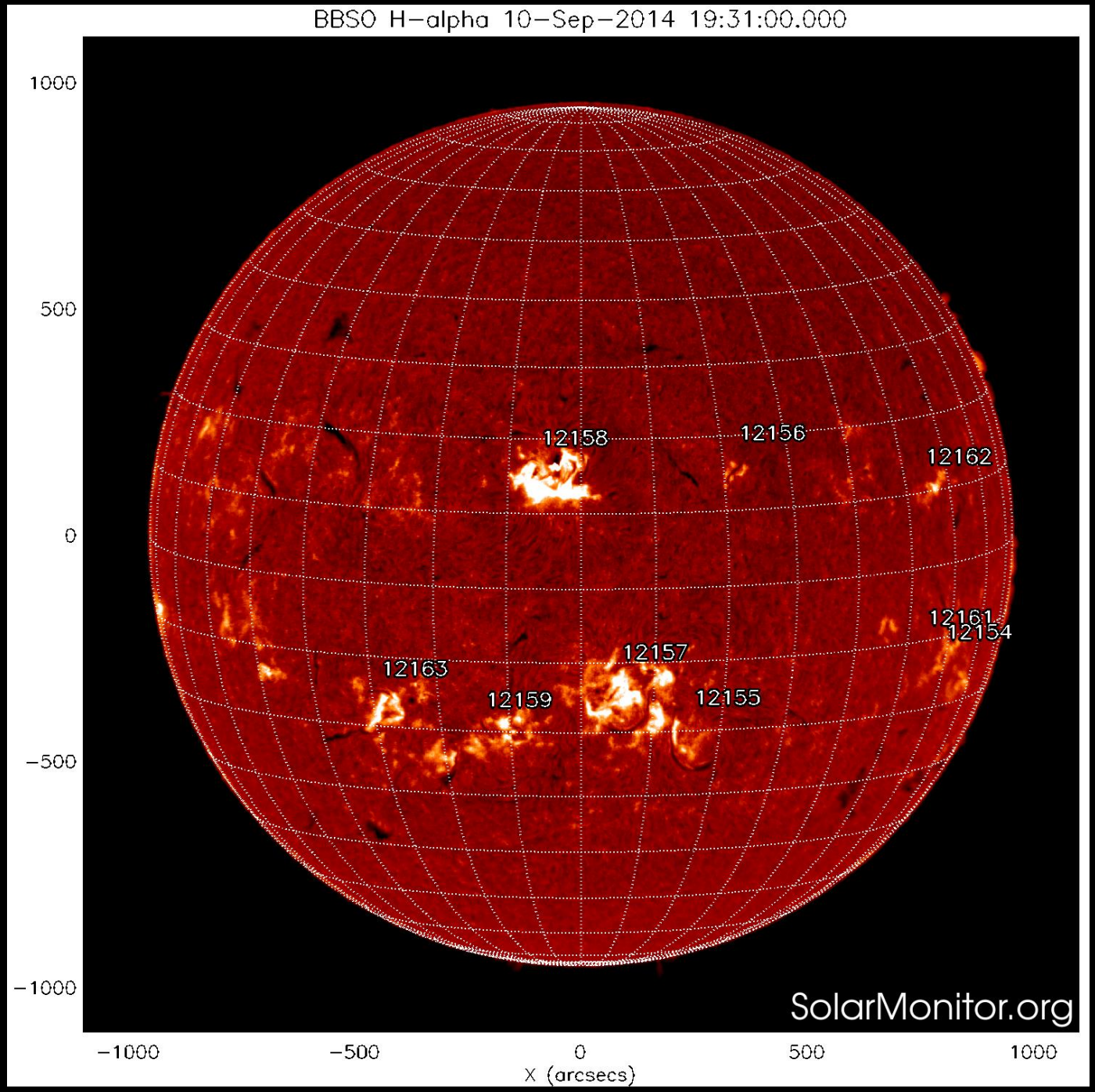


Average Time Between the Two Maxima/Minima = 11 years

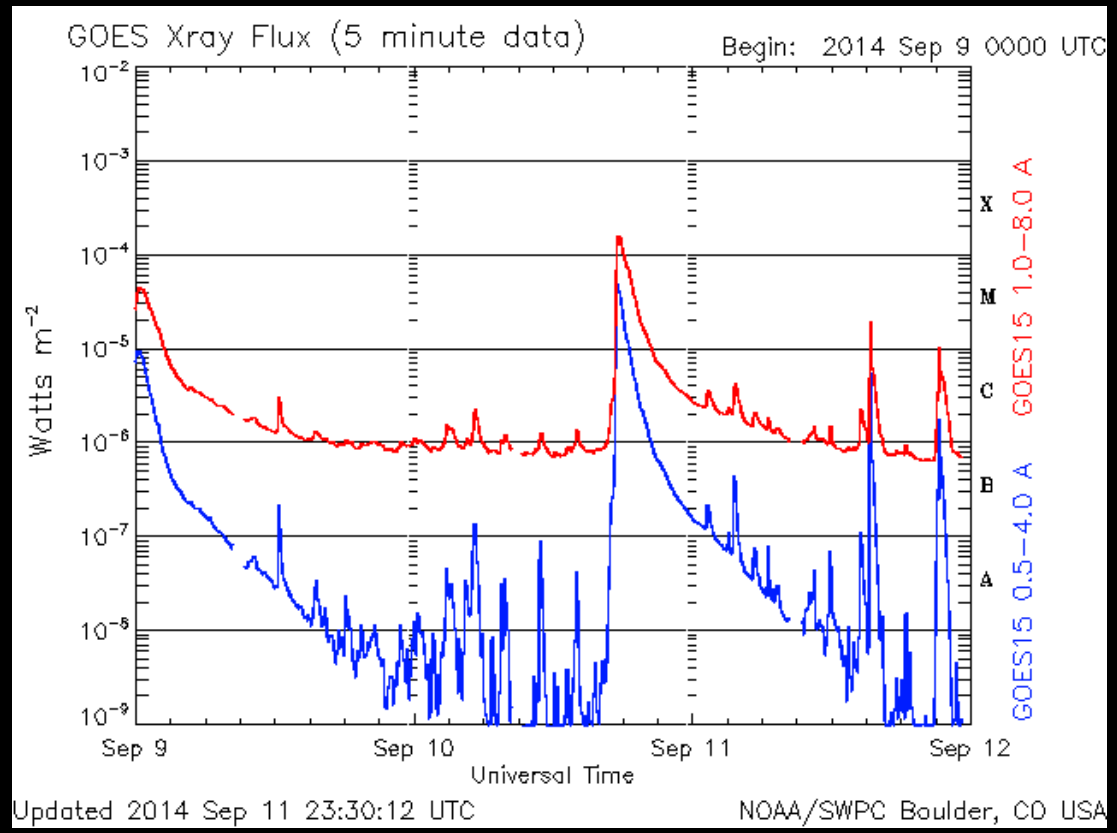
Image Used with Permission from Dr. David Hathaway

Flare, as Seen from the Solar Dynamics Observatory in Extreme Ultraviolet Light





Active Region (AR) 12158 produced a X1.6 flare



Let's Summarize So Far

The Sun is a star that produces many "colors" of light:
γ rays, X rays, UV, visible, IR, μwave, radio.

The Sun produces spots on its "surface" (photosphere), darker and cooler than the surrounding unspotted area.

These sunspots appear and disappear cyclically, the Sunspot Cycle, with approximately eleven years between maxima or minima.

The Sun produces bursts of energy called flares. We measure flares with a satellite that detects X rays. The brightest flares are called X-class.

What IS Space Weather?

Well, What is Weather?

Image from https://gpm.nasa.gov/education/weather-climate

Short Term Conditions

Temperature

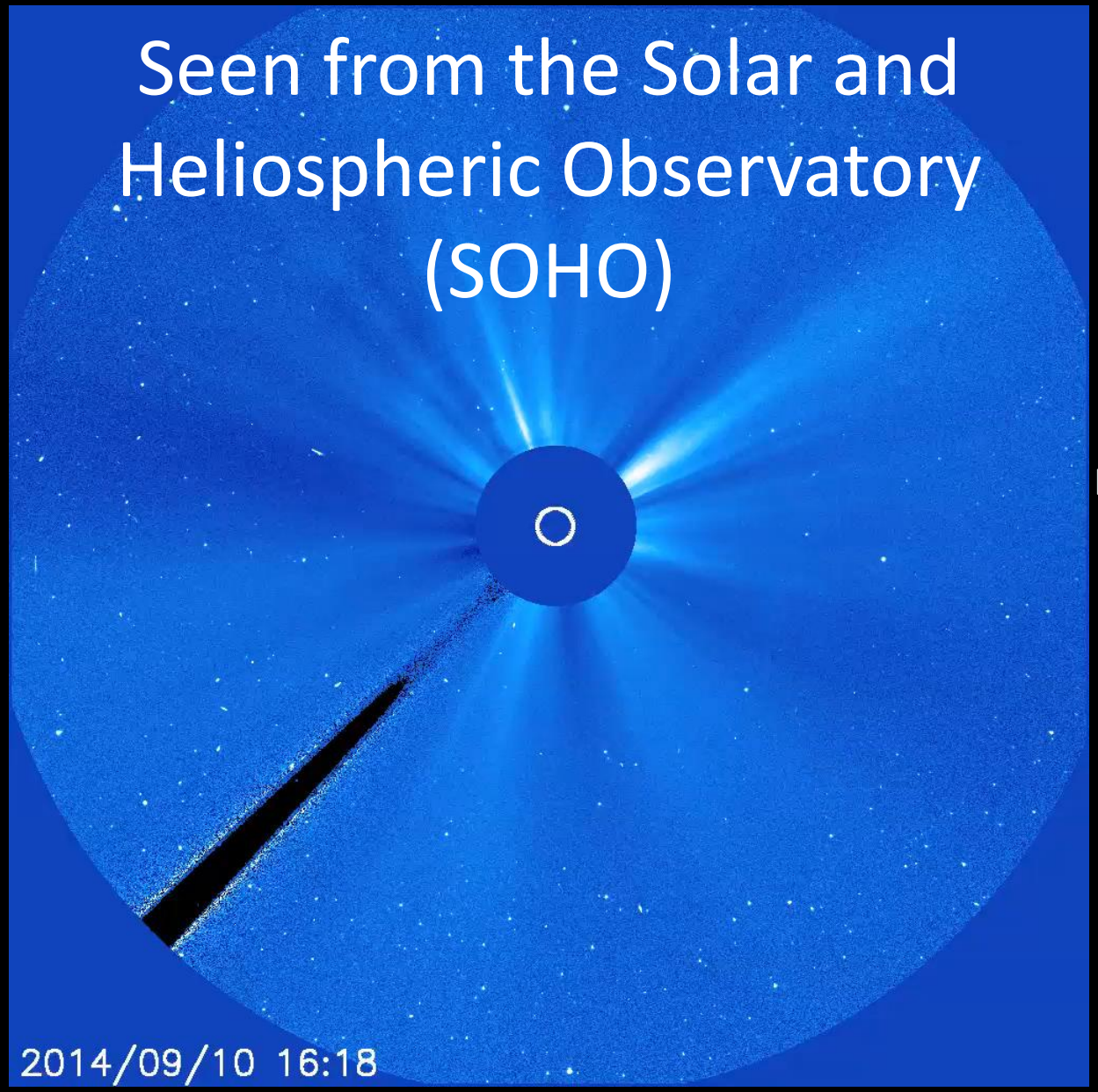
Sunny or Cloudy

Rain or Dry

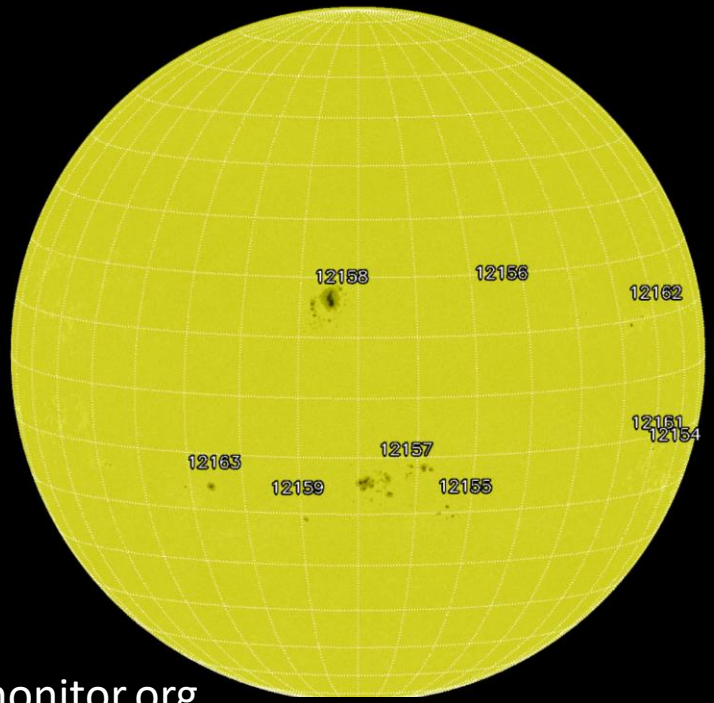
Windy or Not

What do I wear?

AR 12158 Coronal Mass Ejection

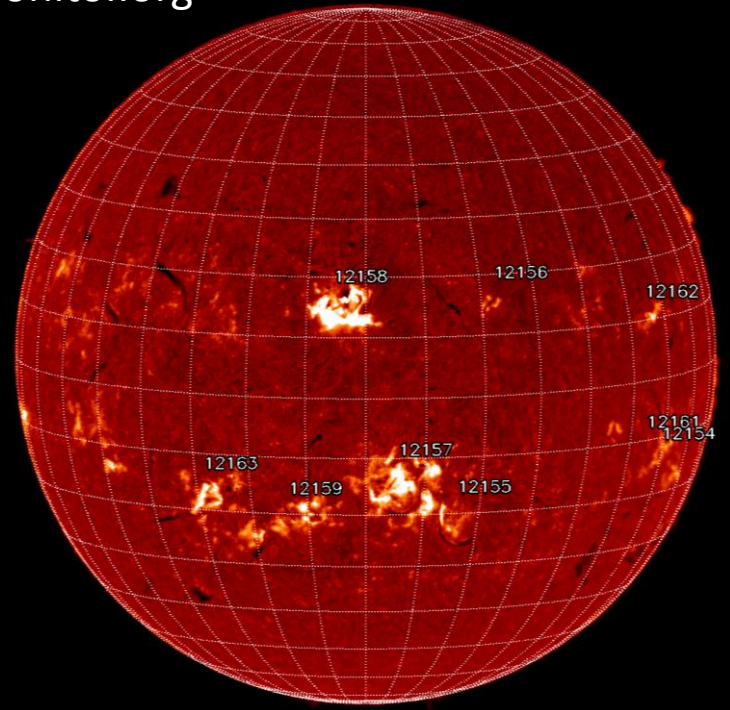


Solar Dynamics Observatory (SDO), “visible” light



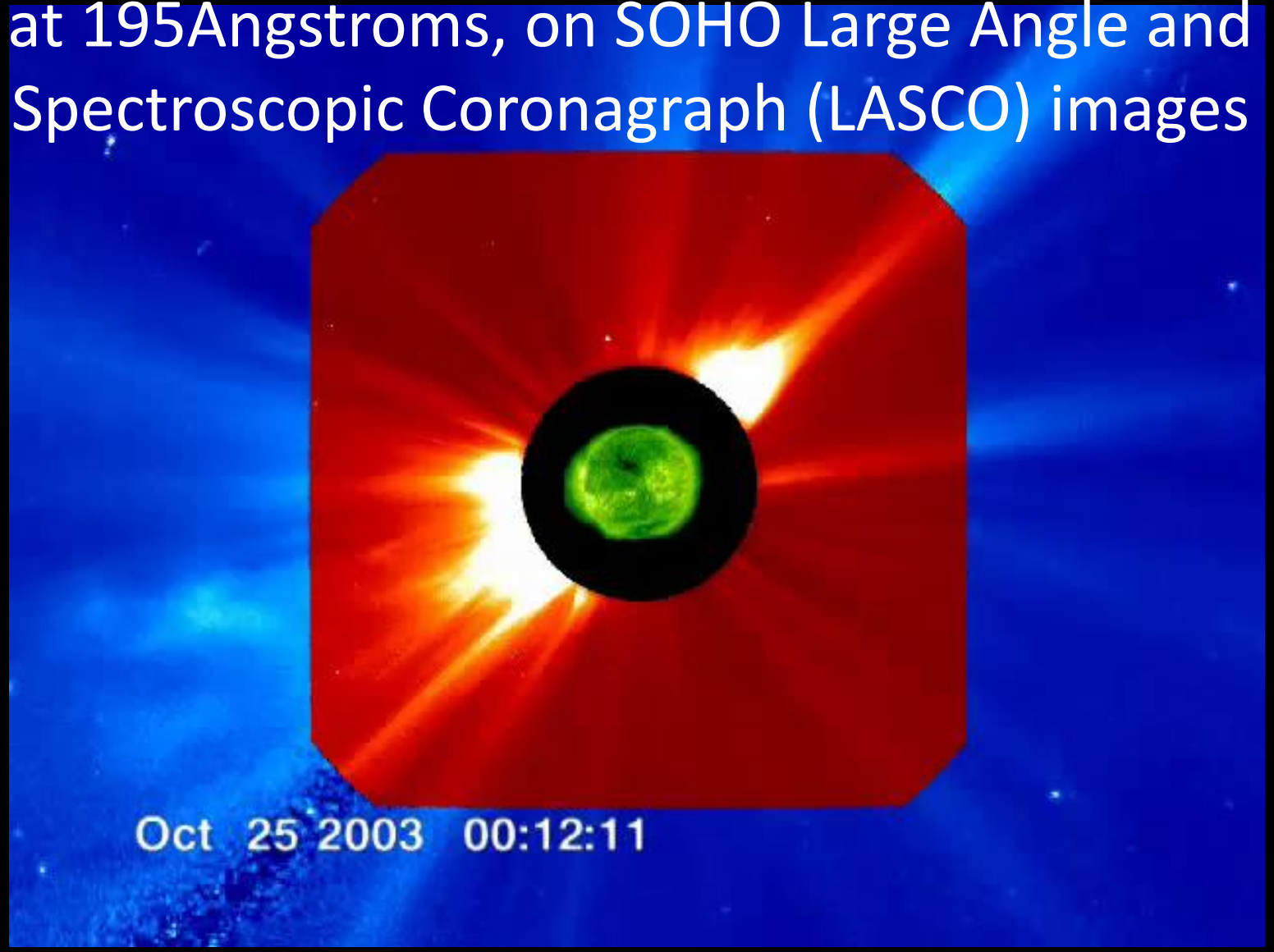
Both from https://solarmonitor.org

Big Bear Solar Observatory (BBSO), Hydrogen-alpha light

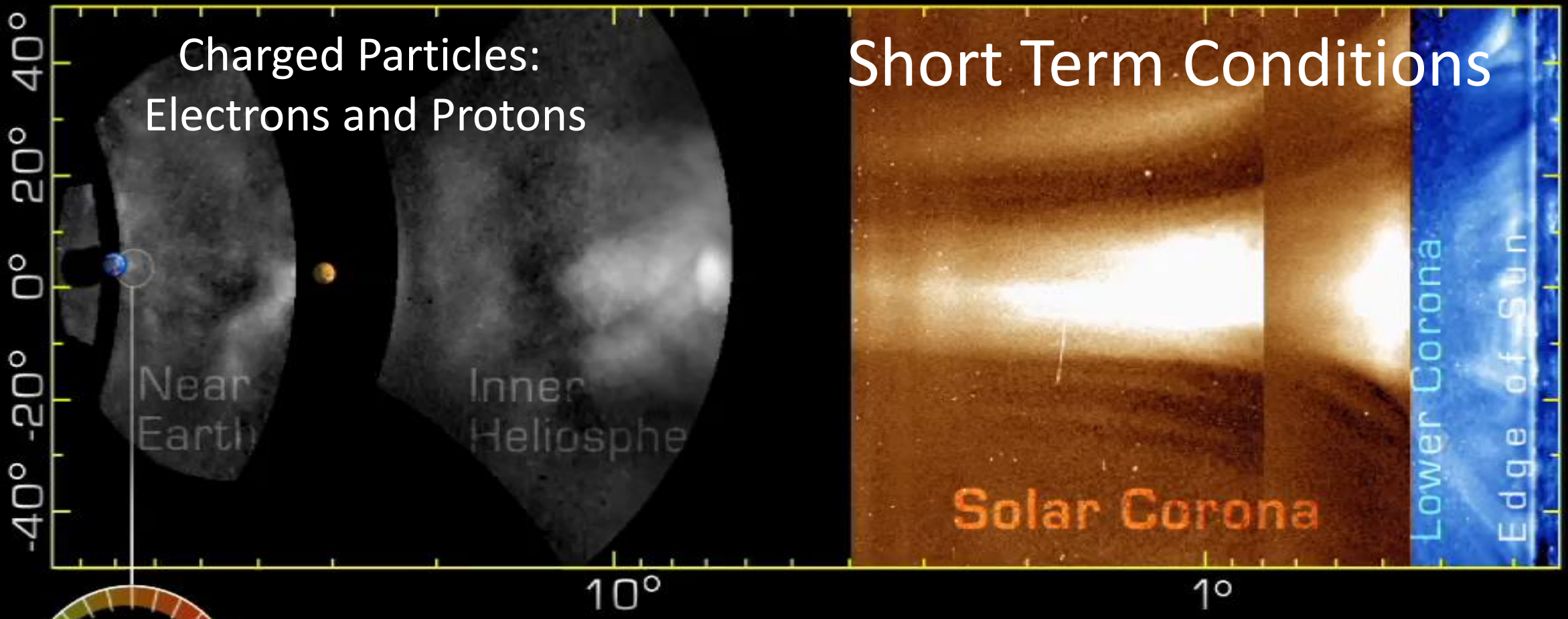


The “Halloween Events”

SOHO Extrememe Ultraviolet ImagingTelescope (EIT) at 195Angstroms, on SOHO Large Angle and Spectroscopic Coronagraph (LASCO) images



What is SPACE Weather?

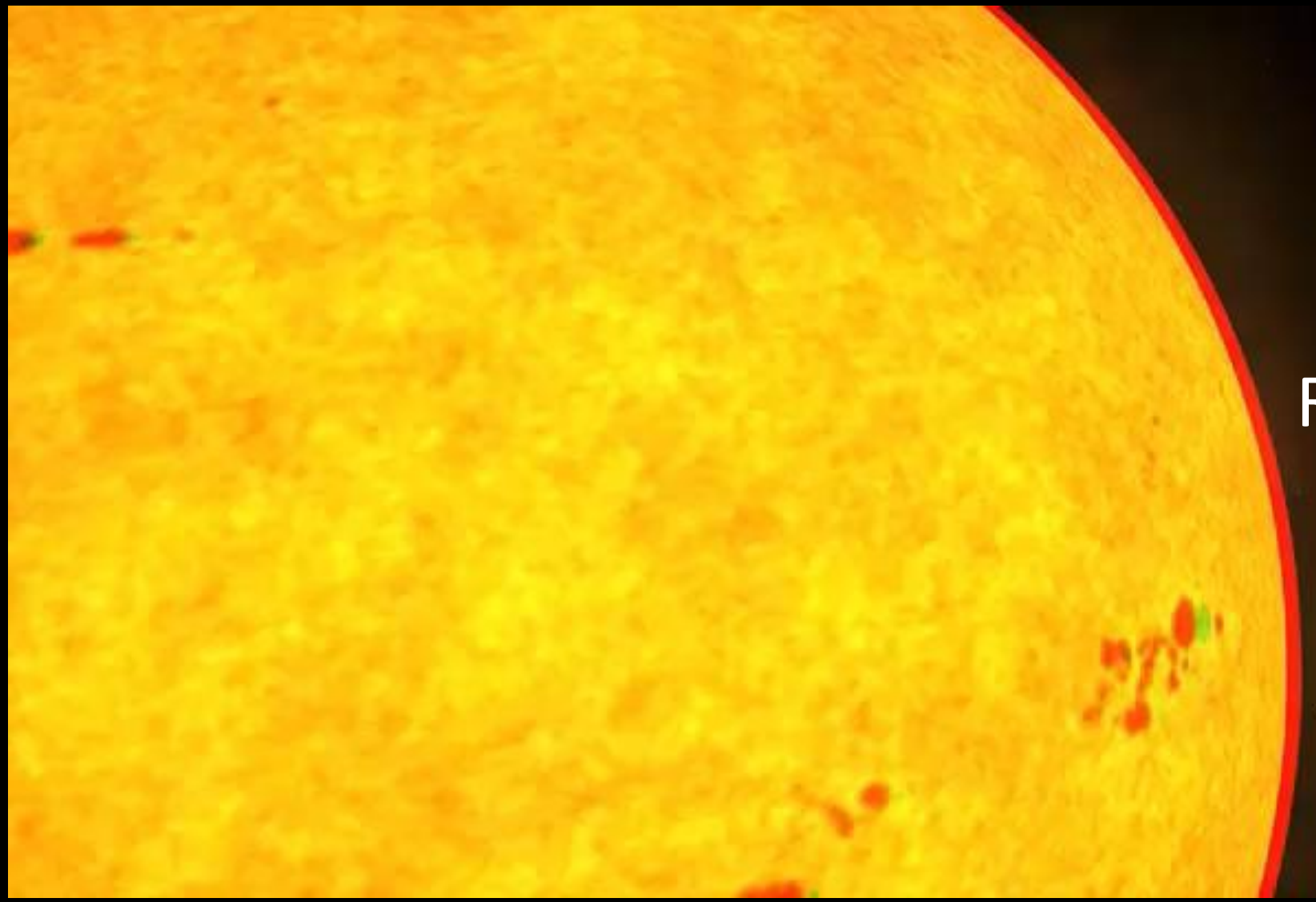


"Windy"

Animation from https://svs.gsfc.nasa.gov/10809

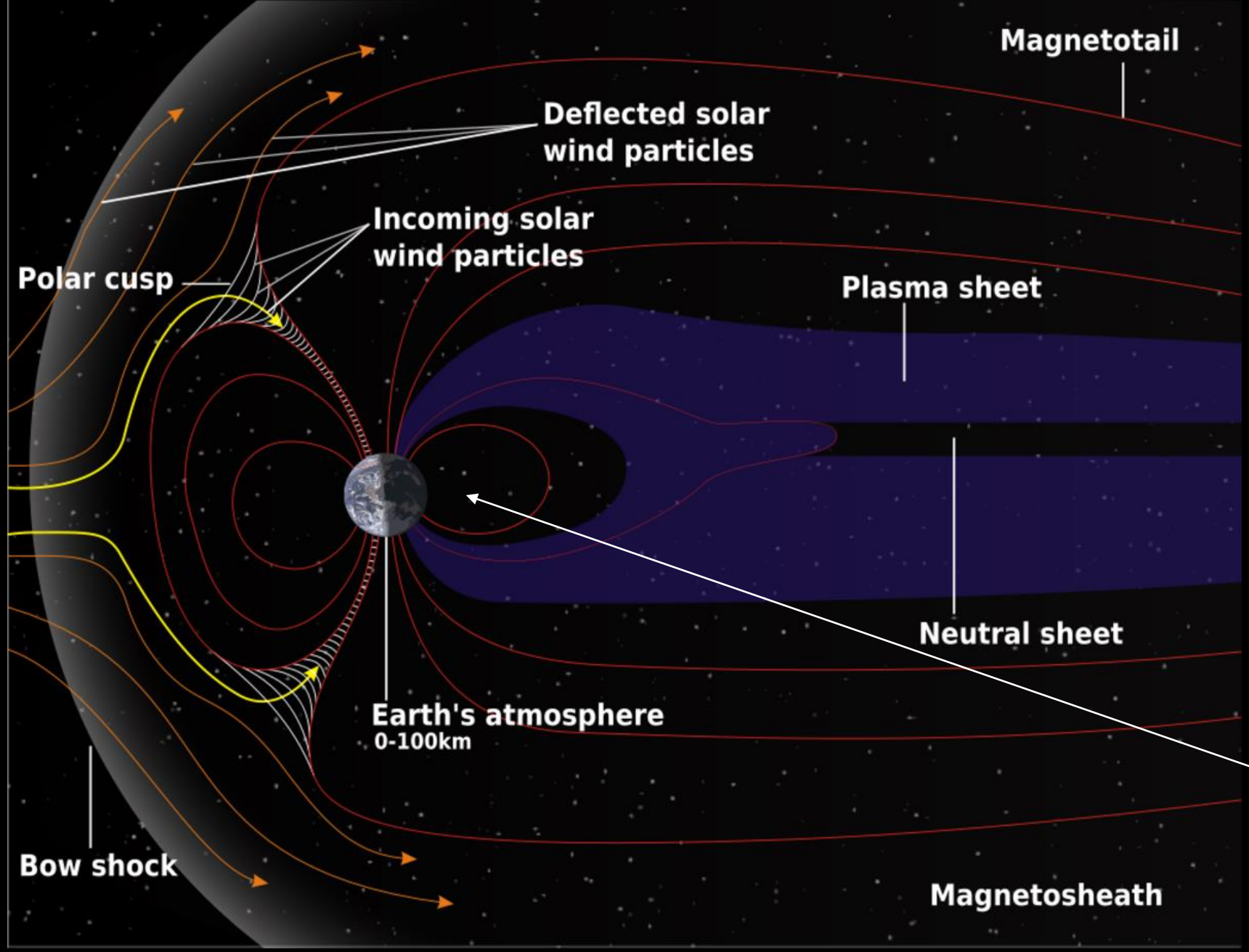
Credit: NASA/Goddard Space Flight Center/SwRI/STEREO/WIND

Space Weather: From Sun to Earth



Magnetic Reconnection: At the Sun and Earth

Animation from NASA/Goddard Space Flight Center Conceptual Image Lab: https://svs.gsfc.nasa.gov/20101



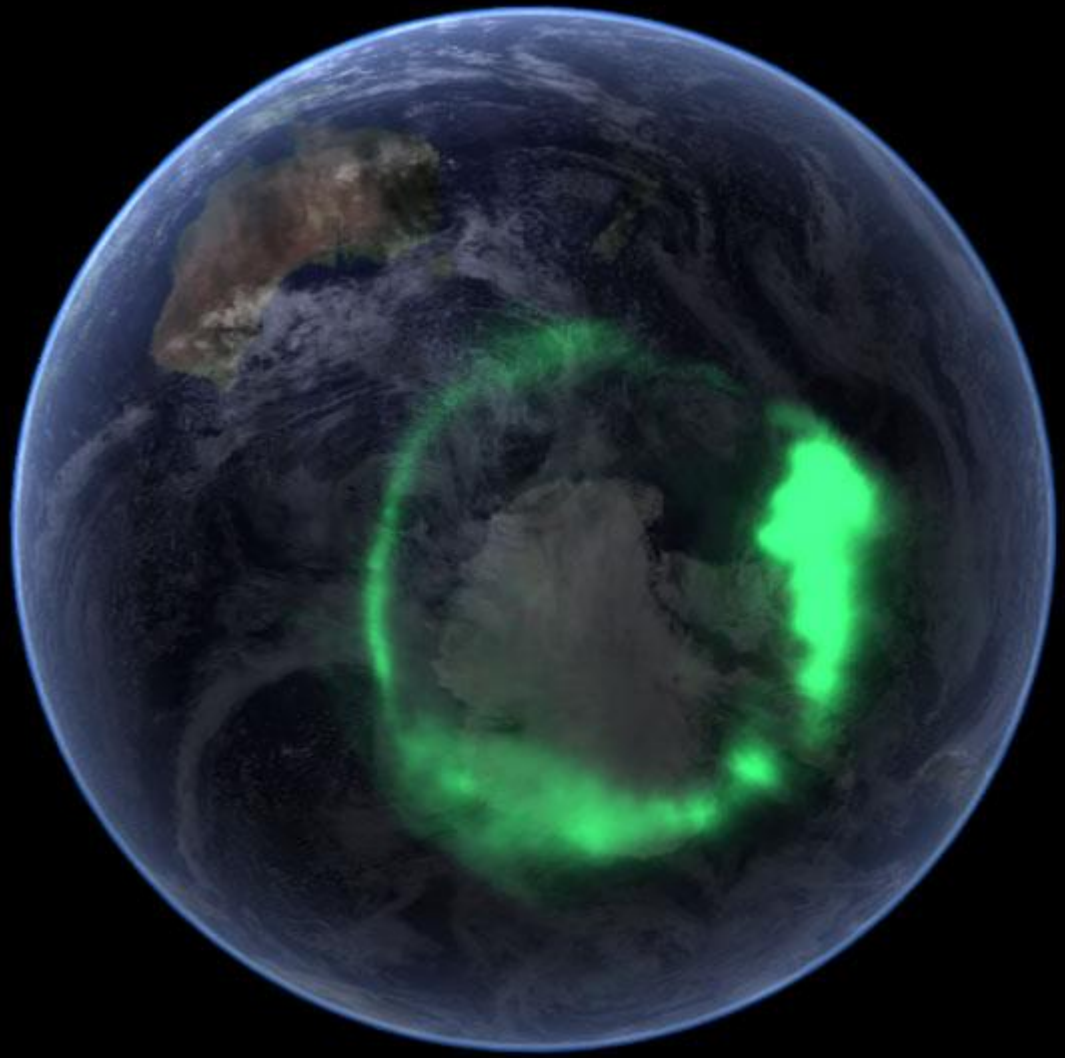
Earth's
Magnetic field
Shields Against the Erosion
of our Atmosphere
and
Repels Energetic
Particles that
are Damaging to
Life on Earth

Particles from Earth's atmosphere exist out here. These particles rain down on polar areas to cause Aurorae.

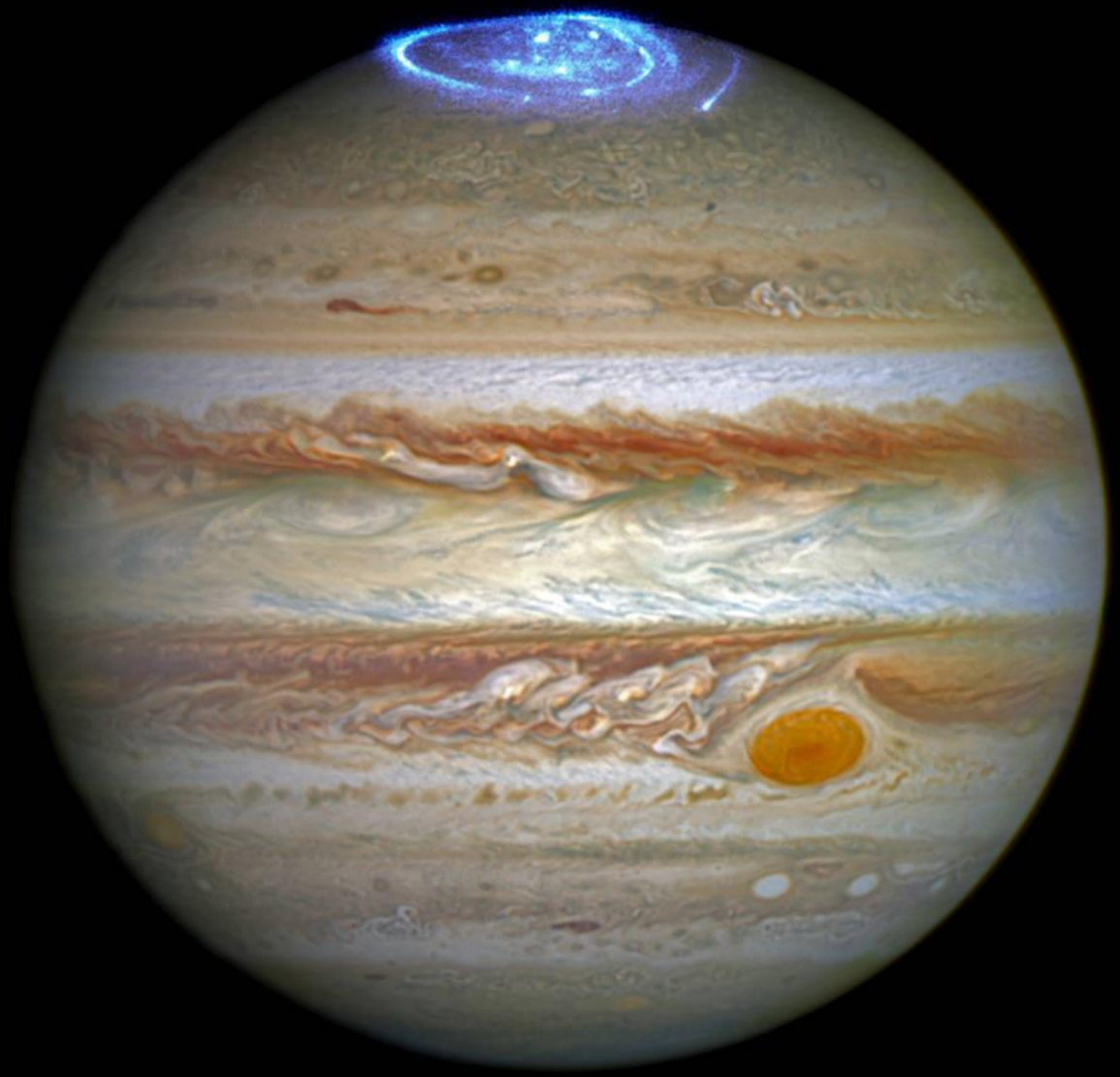
Structure of Earth's Magnetosphere courtesy of Wikipedia Commons

Auroral Oval Over Antarctica September 11, 2005

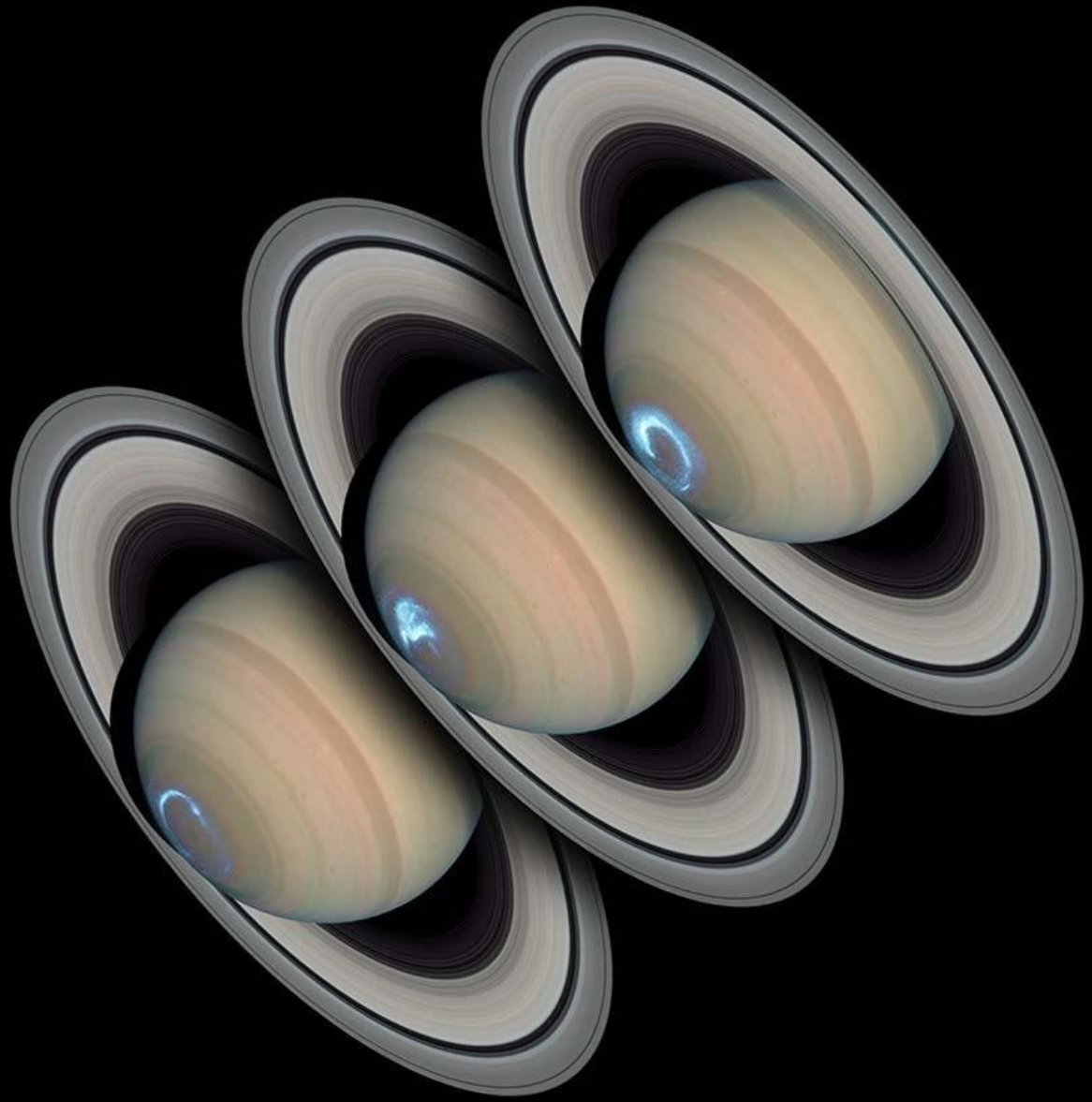
Back to Weather Analogy: Precipitation



Composite Image: UltraViolet-emitting auroral oval as seen from NASA's IMAGE satellite overlaid on NASA's Blue Marble image.



https://www.nasa.gov/feature/goddard/2016/hubble-captures-vivid-auroras-in-jupiter-s-atmosphere



https://solarsystem.nasa.gov/resources/12369/saturns-auroras

Space-Weather Effects

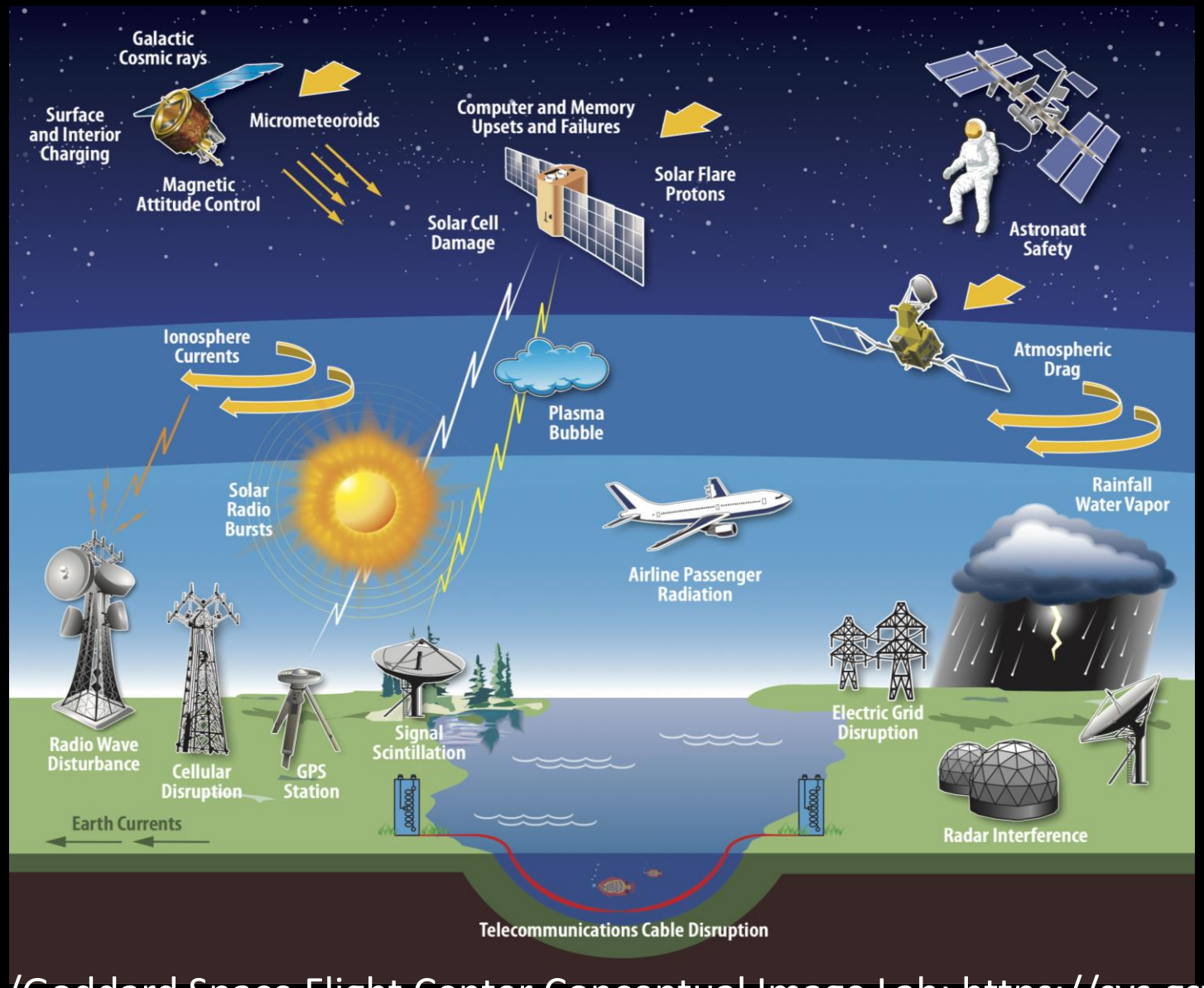


Image from NASA/Goddard Space Flight Center Conceptual Image Lab: https://svs.gsfc.nasa.gov/4923

This Just In!!

(well sort of)

From https://www.swpc.noaa.gov/news/geomagnetic-storm-conditions-likely-2-3-february-2022

February 3, 2022
SpaceX launches 49 Starlink satellites

February 4, 2022
A Minor Geomagnetic Storm Began

Summary

- The Sun is a Dynamic Star.
- Sunspots are cooler than their surroundings.
- The Sun has an activity cycle of approximately eleven years.
- During the maximum of this cycle, the Sun produces more spots, and is more likely to produce space-weather events…but can happen at any time.
- Space-weather events can produce effects at Earth and at any planet in the solar system with a magnetic field.
- Earth’s magnetic field and atmosphere protects Earth from some of the most damaging effects.
- Aurorae happen when Earth’s atmospheric particles, mostly electrons, precipitate back down into the lower atmosphere…energized by magnetic reconnection.
- Always check the weather report.

Now We Pause for a Poll!

https://pollev.com/mitziadams505

Post: Rate how interested you are in space science.

A. Not at all interested

B. Moderately interested

C. Interested

D. Super interested

Post: Is the Sun a star?

A. Yes

B. No

C. Maybe

Post: Is a sunspot cooler than its surroundings?

A. Yes

B. No

C. Maybe

Post: Aurorae are caused by solar-wind particles hitting Earth's atmosphere.

A. True

B. False

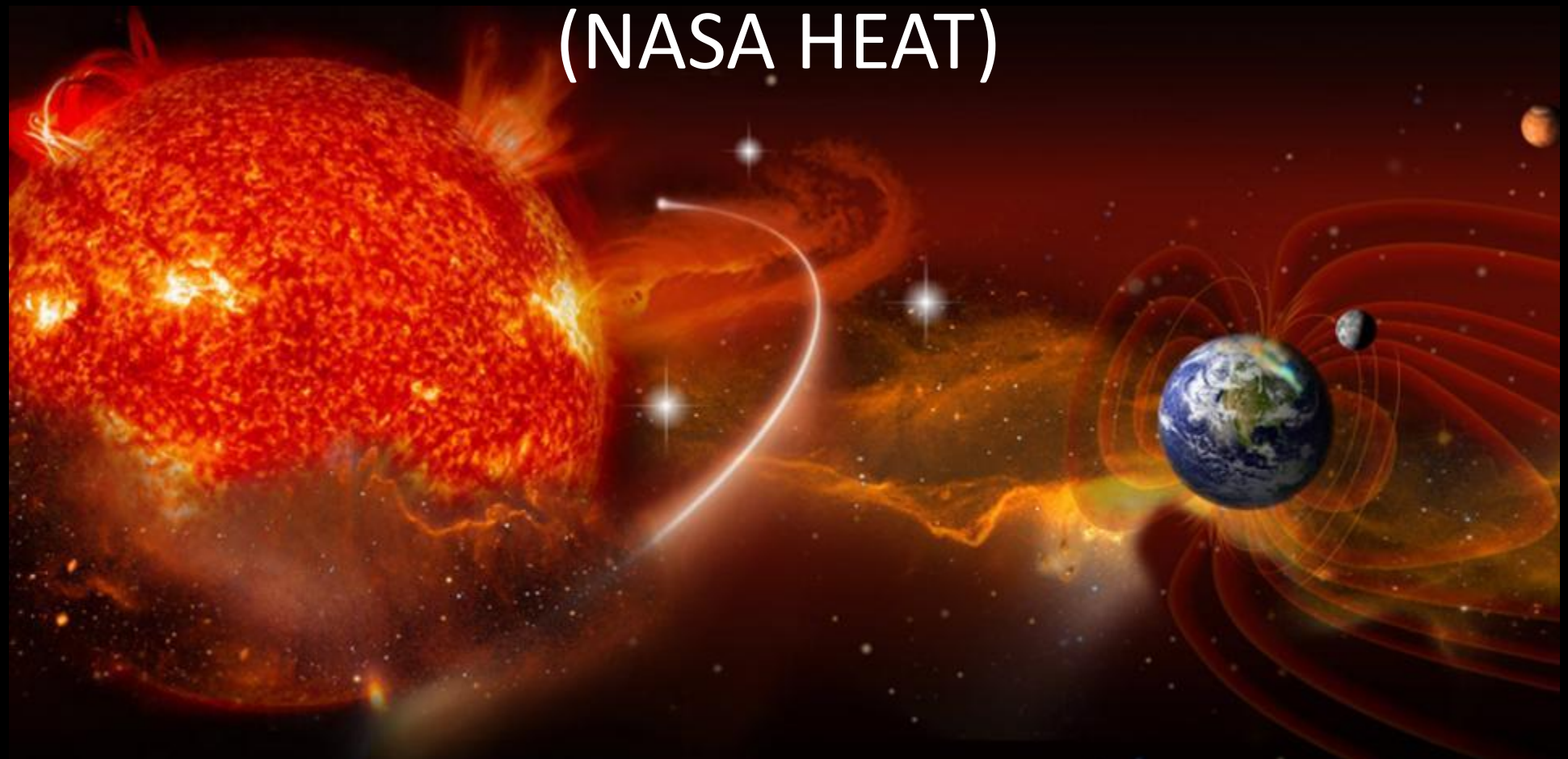
How's my driving?

(was the information clearly presented?)

Two Solar Eclipses over the United States

Image Used with Permission from Dr. Angela Speck

NASA Heliophysics Education Activation Team (NASA HEAT)



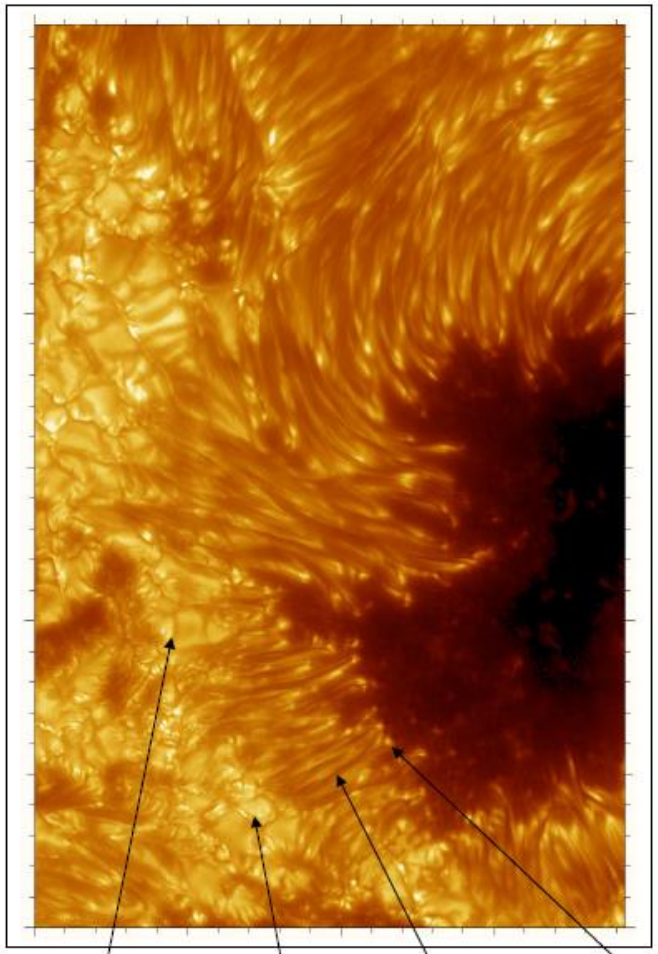
My participation is partially sponsored by NASA HEAT, who bring engaging educational programs about heliophysics to the world

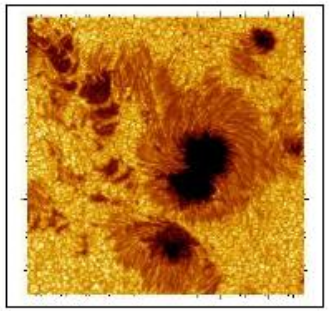
Image from
https://science.nasa.gov/science-activation-team/nasa-heliophysics-education-activation-team

Backup Slides

Solar Surface Details

The sun is our nearest star. From Earth we can see its surface in great detail. The images below were taken with the 1-meter Swedish Vacuum Telescope on the island of La Palma, by astronomers at the Royal Swedish Academy of Sciences (http://www.astro.su.se/groups/solar/solar.html). The image to the right is a view of sunspots on July 15, 2002. The enlarged view to the left shows never-before seen details near the edge of the largest spot. Use a millimeter ruler, and the fact that the dimensions of the left image are 19,300 km x 29,500 km, to determine the scale of the photograph, and then answer the questions. See the arrows below to identify the various solar features mentioned in the questions.





Question 1 - What is the scale of the image in km/mm?

Question 2 – What is the smallest feature you can see in the image?

Question 3 – What is the average size of a Solar Granulation region?

Question 4 – How long and wide are the Dark Filaments?

Question 5 – How large are the Bright Spots?

Question 6 – Draw a circle centered on this picture that is the size of Earth (radius = 6,378 km). How big are the features you measured compared to familiar Earth features?

From Spacemath:
https://spacemath.gsfc.nasa.gov/sun/2page14.pdf

Question 1 - What is the scale of the image in km/mm? **Answer:** the image is about 108mm x 164mm so the scale is 19300/108 = 179 km/mm.

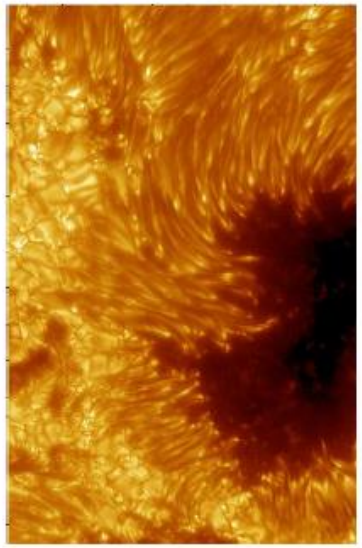
Question 2 – What is the smallest feature you can see in the image? **Answer:** Students should be able to find features, such as the Granulation Boundaries, that are only 0.5 mm across, or 0.5 x 179 = 90 km across.

Question 3 – What is the average size of a Solar Granulation region? **Answer:** Students should measure several of the granulation regions. They are easier to see if you hold the image at arms length. Typical sizes are about 5 mm so that 5 x 179 is about 900 km across.

Question 4 – How long and wide are the Dark Filaments? **Answer:** Students should average together several measurements. Typical dimensions will be about 20mm x 2mm or 3,600 km long and about 360 km wide.

Question 5 – How large are the Bright Spots? **Answer:** Students should average several measurements and obtain values near 1 mm, for a size of about 180 km across.

Question 6 – Draw a circle centered on this picture that is the size of Earth (radius = 6,378 km). How big are the features you measured compared to familiar Earth features? **Answer:** See below.



Granulation Region – Size of a large US state.

Bright Spot – Size of a small US state or Hawaii

Filament – As long as the USA, and as narrow as Baja California or Florida.

From Spacemath, page 2:
https://spacemath.gsfc.nasa.gov/sun/2page14.pdf

Types of Space Weather

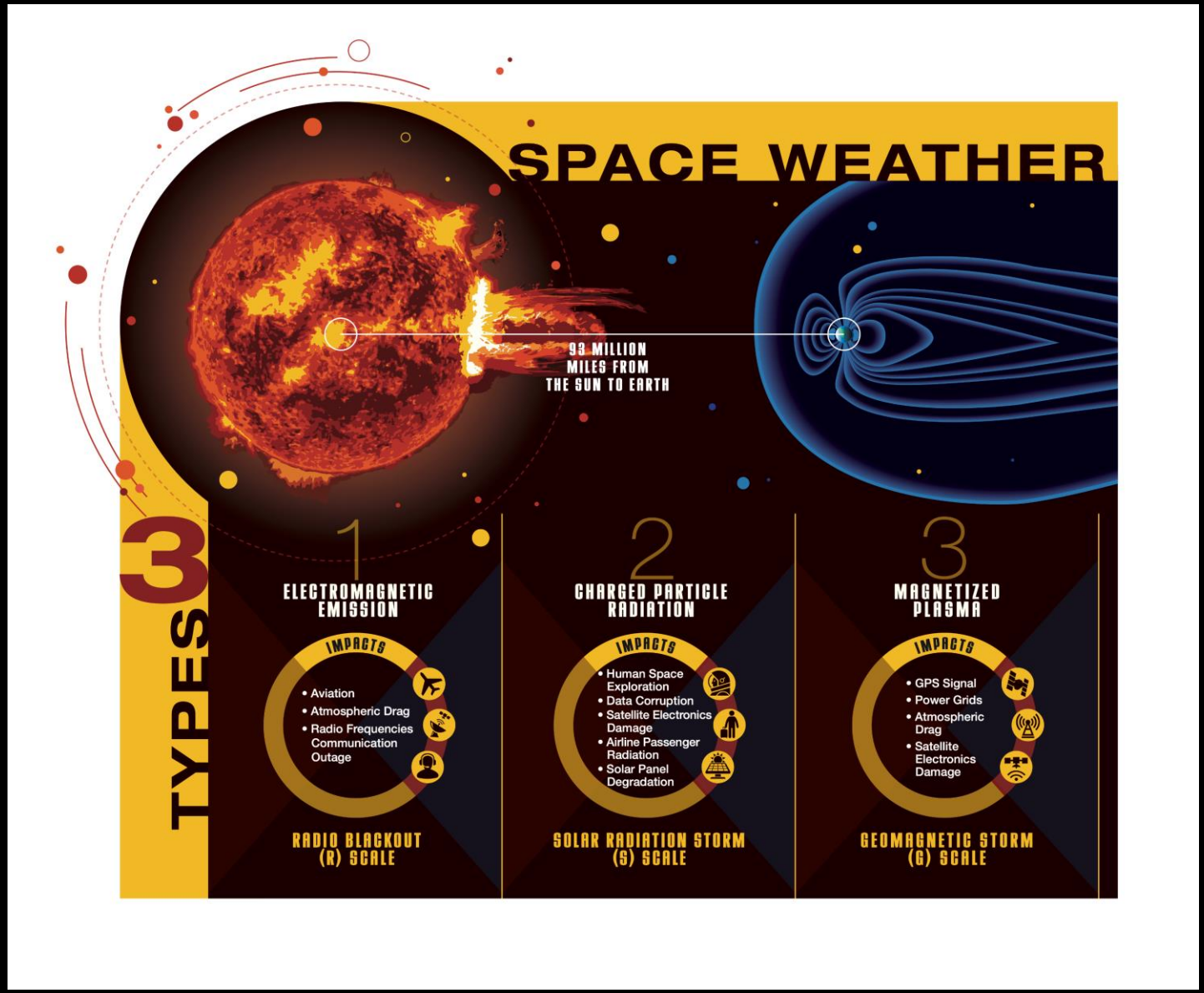


Image from NASA/Goddard Space Flight Center Conceptual Image Lab: https://svs.gsfc.nasa.gov/4923